



This document includes Section 3.0, CVN 68 Class Vessels: Nuclear Steam Propulsion Aircraft Carriers, of the Draft EPA Report "Surface Vessel Bilgewater/Oil Water Separator Feasibility Impact Analysis Report" published in 2003. The reference number is: EPA-842-D-06-019

**DRAFT**  
**Feasibility Impact Analysis Report**  
**Surface Vessel Bilgewater/Oil Water**  
**Separator**

Section 3.0 – CVN 68 Class Vessels: Nuclear Steam  
Propulsion Aircraft Carriers

2003

## SECTION 3.0 – CVN 68 CLASS

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### 3.0 CVN 68 CLASS

The USS NIMITZ Class (CVN 68) was selected to represent the group of operational surface vessels that use nuclear propulsion. The CVN 68 Class is the Navy's latest and largest class (9 vessels) of nuclear aircraft carriers. Each vessel in this class generates approximately 2,703,000 gallons of bilgewater within 12 nautical miles (nm) and approximately 14,620,000 gallons of bilgewater beyond 12 nm annually. The total volume of bilgewater generated within 12 nm is calculated by adding the volume of bilgewater generated in port to the volume generated while operating within 12 nm (e.g., steaming within 12 nm that occurs while transiting out to 12 nm). CVN 68 Class vessels spend 150 days annually within 12 nm of shore; 147 of those days are spent in port and 3 cumulative days are spent in transit. CVN 68 Class vessels operate 215 days annually beyond 12 nm of shore (Navy and EPA, 2003). The in-port bilgewater generation rate for each vessel is 17,000 gallons per day (gpd), and the underway (both transiting and beyond 12 nm) rate is 68,000 gpd (Navy and EPA, 2003).

Bilgewater generated within 12 nm:

$$\frac{147 \text{ days (pierside)}}{\text{yr}} \bullet \frac{17,000 \text{ gal}}{\text{day}} + \frac{3 \text{ days (underway)}}{\text{yr}} \bullet \frac{68,000 \text{ gal}}{\text{day}} = 2,703,000 \text{ gal/yr}$$

Bilgewater generated beyond 12 nm:

$$\frac{215 \text{ days (underway)}}{\text{yr}} \bullet \frac{68,000 \text{ gal}}{\text{day}} = 14,620,000 \text{ gal/yr}$$

CVN 68 Class vessels are equipped with either two 50 gallons per minute (gpm) Facet model C-50 gravity coalescence type oil water separators (OWSs) for a total processing capacity of 100 gpm or two 90-gpm Facet model C-50RF01 OWSs. The two 50-gpm C-50 OWSs were chosen to support this analysis because they are the most prevalent OWSs used on CVN 68 Class vessels. Because the capacity of the current marine pollution control device (MPCD) is used to select the capacities of each potential MPCD option group analyzed, selecting the gravity coalescence units with the lower capacity enables the selection of lower capacity units for the remaining MPCD option groups. Lower capacity units are generally smaller in size. The CVN 68 Class vessels operate two 90-gpm pumps to offload oily wastewater and one 90-gpm pump to offload waste oil (Jarnigan, 2001).

To the extent possible, the current MPCD was used to select the capacities and quantities of each MPCD evaluated in the feasibility analysis. The following MPCDs are evaluated in this feasibility analysis for CVN 68 Class vessels: gravity coalescence, centrifuge, collection, holding, and transfer (CHT), evaporation, hydrocyclone, *in situ* biological treatment, oil absorbing sock, filter media, and membrane filtration.

#### 3.1 GRAVITY COALESCENCE

The following sections discuss the feasibility and cost impacts of installing and operating a gravity coalescer on-board a CVN 68 Class vessel.

### 3.1.1 Practicability and Operational Impact Analysis

This section describes the analyses of specific feasibility criteria relative to the physical characteristics and operational requirements of gravity coalescence units.

#### 3.1.1.1 *Space and Weight*

As described in Section 3.0, the analysis of gravity coalescence will include two 50-gpm gravity coalescence units (C-50) and two 90-gpm pumps. The gravity coalescence OWS units on-board these vessels are intended for single-deck operation and are commonly installed in the OWS room. Table 3-1 provides the space and weight for the C-50.

**Table 3-1. C-50 Specifications (CVN 68 Class)**

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft <sup>3</sup> )	Weight (lbs.) Dry/Flooded
Per unit	1	50 gpm	6 x 2.7 x 5	10 x 4.7 x 7	81.3	2400/4500
Total (To achieve required processing capacity)	2	100 gpm	-	-	163	4800/9000

Clearance is required above the OWS tank assembly to mount chain falls for removal of the tank cover. The envelope for installation and maintenance remain the same.

#### 3.1.1.2 *Personnel/Equipment Safety*

There are no unusual personnel or equipment safety hazards associated with gravity coalescence units. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use on-board vessels of the Armed Forces. Standard afloat control and management procedures are adequate for use and disposal of the material. While gravity coalescence units require electrical power, existing standard shipboard safety procedures for handling electrical equipment have been adequate to protect personnel and safety.

#### 3.1.1.3 *Mission Capabilities*

The use of C-50 gravity coalescence type OWSs on CVN 68 Class vessels has not resulted in any impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

#### 3.1.1.4 *Personnel Impact*

The C-50 separators operate in automatic mode but require general supervision while the unit is operating. Based on a combined bilgewater processing rate of 100 gpm (for both units) and the approximate 2,703,000 gallons of bilgewater generated annually within 12 nm, the number of hours each gravity coalescer is operated annually within 12 nm is approximately 450 hours.

$$\frac{2,703,000 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{100 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} = 450 \text{ hrs/yr}$$

Based on operational experience, the time required per year to supervise the operation of a C-50 separator is approximately 0.25 hours (15 minutes) for every two hours the unit operates. The supervisory labor requirement of 0.25 hours for every two hours of operation is based on the assumption that although the unit is automatic, a crewmember will be assigned to supervise the operation of multiple pieces of equipment at once. Therefore, the time required to oversee both C-50 units is assumed to be the same as for a single unit. Based on the annual operating requirement of 450 hours, the annual labor requirement associated with the operation of both gravity coalescence units within 12 nm is 56 hours, as calculated below:

$$\frac{450 \text{ hrs operation}}{\text{yr}} \cdot \frac{0.25 \text{ hr labor}}{2 \text{ hrs operation}} = 56 \text{ hrs labor/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires three crewmembers per event. One crewmember is required to operate the waste oil transfer pump and associated valves/hull connections. A second crewmember is required to oversee the connection of transfer hoses for the offloading vessel. A third crewmember oversees the connection of transfer hoses for the receiving vessel or facility. The two crewmembers overseeing the transfer hose connections stand by the hose connections in case the connections separate. The two crewmembers also ensure that appropriate precautions are taken to prevent oil spills. During waste oil transfer activities, two-way voice communication is established between the three crewmembers overseeing the oil transfer (Navy, 2002). The labor hours associated with transferring the waste oil produced within 12 nm from shore by both gravity coalescence units on CVN 68 Class carriers are calculated by dividing the waste oil volume (1 percent of the annual bilgewater volume generated while operating within 12 nm) by the waste oil pump rate (90 gpm) and multiplying by the number (three) of crew members.

$$\frac{27,030 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{90 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} \cdot \frac{3 \text{ hrs labor}}{\text{hr}} = 15 \text{ hrs labor/yr}$$

The combined annual labor associated with the operational oversight of both gravity coalescence units within 12 nm, 56 hours, and transfer of waste oil generated within 12 nm, 15 hours, on a CVN 68 Class vessel is 71 hours.

The total labor requirement associated with vessel operations beyond 12 nm includes MPCD operator oversight (i.e., 0.25 hours for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore, attributable to vessel operation beyond 12 nm. The annual labor requirement associated with operating this MPCD beyond 12 nm is calculated using the same methodology used to calculate the annual labor requirement within 12 nm. The approximate volume (i.e., 14,620,000 gal) of bilgewater generated beyond 12 nm and resultant volume (i.e., 146,200 gal) of waste oil that requires offloading to shore are based on the CVN 68 Class vessel underway bilgewater generation rate of 68,000 gpd. The underway

generation rate is multiplied by the number of days (215 days) spent beyond 12 nm. Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{14,620,000 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{100 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} = 2,440 \text{ hrs/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{2,440 \text{ hrs}}{\text{yr}} \cdot \frac{0.25 \text{ hrs labor}}{2 \text{ hrs}} = 305 \text{ hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{146,200 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{90 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} \cdot \frac{3 \text{ hrs labor}}{\text{hr}} = 81 \text{ hrs labor/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of two C-50 separators on a CVN 68 Class vessel class beyond 12 nm is 386 hrs/yr.

Annually, each C-50 requires approximately 87.1 personnel hours of time-based maintenance, 0 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 3-2 and Table 3-3 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for one C-50 separator.

**Table 3-2. C-50 Time-Based Maintenance Hours (CVN 68 Class)**

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Check Pressure Gage Indications	0.3	1 week	15.6
Check Valve Actuator Cam Adjustments	0.3	1 week	15.6
Check Adjustment of Pressure Reducing Valve	0.3	1 month	3.6
Clean and Inspect Electrical Control Panel	1.6	3 months	6.4
Inspect and Lubricate Swing Check Valve	1.4	3 months	5.6
Lubricate Solenoid Valve Linkage	0.2	3 months	0.8
Clean and Inspect Conductance Type Level Sensor	0.5	3 months	2
Clean and Inspect OWS Tank	16	6 months	32
Lubricate Simplex Strainer	0.3	6 months	0.6
Test Relief Valve	0.2	6 months	0.4
Clean and Inspect Flow Totalizer	1.0	6 months	2

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Clean and Inspect Motorized Ball Valve(s)	1.5	12 months	1.5
Test Operate Pumps	0.6	12 months	0.6
Total Annual Labor per unit			86.7
Total Annual Labor per vessel			173.4

**Table 3-3. C-50 Condition-Based Maintenance Hours (CVN 68 Class)**

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 500 operation hours within 12 nm)	Annualized Maintenance Hours (based on 3000 operation hours beyond 12 nm)
None	0	0	0	0
Total Annualized Hours	-	-	0	0

Table 3-4 provides the annual labor hours required to operate and maintain the C-50 units.

**Table 3-4. C-50 Annual Labor Hours (CVN 68 Class)**

	Gravity Coalescer (C-50)
Operator Hours Within 12 nm	71
Operator Hours Beyond 12 nm	386
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	173.4
Total Time	631

### ***3.1.1.5 Consumables, Repair Parts, and Tools***

The C-50 units installed on CVN 68 Class vessels do not require consumables. No special tools are required for the operation or maintenance of these units.

### ***3.1.1.6 Interface Requirements***

Table 3-5 summarizes specific system interface requirements associated with the C-50 OWS units.



**Table 3-5. C-50 Interface Requirements (CVN 68 Class)**

Shipboard System	C-50 Interface Requirements
Electrical Power	3 kW (4 hp), 440V/3Ph/60Hz
Potable Water	May be used for priming, 25 psi max
Seawater	Requires 25 psi seawater pressure
Drainage	Gravity drain to OWHT

### ***3.1.1.7 Control System Requirements***

The gravity coalescence units installed on-board CVN 68 Class vessels are designed to operate in either automatic or manual mode. Automatic operation is the normal operating mode. When placed in the automatic mode, activation of the units is controlled by tank level switches, which are installed in the OWHT. When the volume of the liquid reaches a pre-set level, one level switch starts the unit(s). When the liquid level in the OWHT drops to a pre-set level, a second level switch signals the unit(s) to shut down. C-50 units have a flow sensor that secures the system if the pump loses suction and a remote alarm/indicator panel that allows shipboard personnel to monitor the operating status of the units while in the automatic mode of operation. The remote alarm/indicator contains visual indicators that allow operating personnel to monitor the overall status of the system and an audible alarm that warns of system malfunction.

In addition, C-50 units installed on CVN 68 Class vessels are equipped with an oil content monitor (OCM) to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than a predetermined concentration, the OCM will redirect the effluent back to the OWHT to be reprocessed by the OWS.

### ***3.1.1.8 Other/Unique Characteristics***

No other/unique characteristics have been identified with respect to this MPCD option.

## **3.1.2 Cost Analysis**

This section describes the analyses of costs associated with using the gravity coalescence units.

### ***3.1.2.1 Initial Cost***

There are no initial costs associated with using gravity coalescence on a CVN 68 Class vessel because the equipment is in place.

### ***3.1.2.2 Recurring Cost***

#### ***Personnel Labor Within 12 nm***

This MPCD requires 245 personnel hours per year for operation, condition-based maintenance, and time-based maintenance within 12 nm, as explained in Section 3.1.1.4. The number of annual labor hours multiplied by the \$22.64 hourly MPCD operator labor rate produces the annual labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{245 \text{ hrs labor}}{\text{yr}} = \$5,560/\text{yr (within 12 nm)}$$

### ***Personnel Labor Beyond 12 nm***

This MPCD requires 386 personnel hours per year for operation outside, and condition-based maintenance beyond 12 nm, as explained under Section 3.1.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{386 \text{ hrs labor}}{\text{yr}} = \$8,730/\text{yr (outside 12 nm)}$$

The labor required to transfer waste oil generated by the gravity coalescence system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose the waste oil at no charge for these vessels.

Table 3-6 summarizes the annual recurring costs for gravity coalescence used on-board a CVN 68 Class vessel.

**Table 3-6. Annual Recurring Costs for Gravity Coalescence (CVN 68 Class)**

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost (\$K)
Within 12 nm	Navy	5.56
Beyond 12 nm	Navy	8.73

### **3.1.2.3 Total Ownership Cost (TOC)**

Table 3-7 summarizes the TOC and annualized cost over a 15-year lifecycle for a gravity coalescence system on a CVN 68 Class vessel.

**Table 3-7. TOC for Gravity Coalescence (CVN 68 Class)**

Cost (\$K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	0	0
Total Recurring	62	180
TOC (15-yr lifecycle)	62	180
Annualized	5.3	15.3

## **3.2 CENTRIFUGE**

The following sections discuss the feasibility and cost impacts of installing and operating a centrifuge on-board a CVN 68 Class vessel.

### 3.2.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of centrifuges.

#### 3.2.1.1 Space and Weight

Two 50-gpm (WSC-50) centrifuge units, for a total processing capacity of 100 gpm, are proposed in this analysis. The two units were chosen because they have the equivalent processing capacity of the current MPCDs in place on CVN 68 vessels. The units are manufactured by a major supplier of centrifuges used in the marine industry and are representative in space, weight, and power requirements of centrifuges with similar processing capacities. Table 3-8 provides the space and weight per unit (includes one 50-gpm centrifuge and heater).

**Table 3-8. WSC-50 Specifications (CVN 68 Class)**

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft <sup>3</sup> )	Weight (lbs.) Dry/Flooded
Per unit	1	50 gpm	6 x 8 x 8.2	7.75 x 10 x 9.2	383	3150/3500
Total (To achieve required processing capacity)	2	100 gpm	-	-	766	6300/7000

The centrifuge is designed for single deck operation and would be installed in the current OWS room. The two existing OWSs would be removed and replaced with two centrifuge units. Installation of these centrifuge units will not result in space or weight impacts. However, based upon a ship check, relocation of an existing 10-inch steam line, a chilled water line, electrical cables, and ducting would be necessary to provide height clearance for the new modules.

#### 3.2.1.2 Personnel/Equipment Safety

Integral heaters provided as part of the centrifuge modules preheat the bilgewater to 90 - 95°C. However, the heater and associated piping are well insulated and will not pose a burn hazard to personnel (Donohue, 2000). Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While centrifuges require electrical power, standard shipboard safety procedures for handling electrical equipment should be adequate.

#### 3.2.1.3 Mission Capabilities

The installation and operation of centrifuges on CVN 68 Class vessels is not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

### 3.2.1.4 Personnel Impact

The WSC-50 centrifuges run in automatic mode, but require general supervision while the unit is operating. Based on a combined bilgewater processing rate of 100 gpm (for both units) and approximately 2,703,000 gallons of bilgewater generated annually within 12 nm, the number of hours each centrifuge is operated annually within 12 nm is 450 hours.

$$\frac{2,703,000 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{100 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} = 450 \text{ hrs/yr}$$

The labor requirement for general oversight of the centrifuge system was calculated as 0.25 hours (15 minutes) for every two hours of operation. The supervisory labor requirement of 15 minutes for every two hours of operation is based on the assumption that although the units are automatic, a crewmember will be assigned to general oversight of multiple pieces of equipment at once. Therefore, based on the annual operating requirement of 450 hours, the annual labor requirement associated with the operation of both centrifuges within 12 nm is 56 hours, as calculated below:

$$\frac{450 \text{ hrs operation}}{\text{yr}} \cdot \frac{0.25 \text{ hr labor}}{2 \text{ hrs operation}} = 56 \text{ hrs/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires three crewmembers per event as described under Section 3.1.1.4. The labor hours associated with transferring the waste oil produced within 12 nm from shore by the centrifuges on CVN 68 Class carriers are calculated by dividing the waste oil volume (1 percent of the annual bilgewater volume generated while operating within 12 nm) by the waste oil pump rate (90 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{27,030 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{90 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} \cdot \frac{3 \text{ hrs labor}}{\text{hr}} = 15 \text{ hrs labor/yr}$$

The combined annual labor associated with the operational oversight of both centrifuge modules within 12 nm and transfer of waste oil generated within 12 nm on a CVN 68 Class vessel is 71 hours.

The total labor requirement associated with vessel operations beyond 12 nm includes MPCD operator oversight (i.e., 15 minutes for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore attributable to vessel operation beyond 12 nm. The annual labor requirement associated with operating this MPCD beyond 12 nm is calculated using the same methodology used to calculate the annual labor requirement within 12 nm. The approximate volume (i.e., 14,620,000 gal) of bilgewater generated beyond 12 nm and resultant volume (i.e., 146,200 gal) of waste oil that requires offloading to shore are based on the CVN 68 Class vessel underway bilgewater generation rate of 68,000 gpd. The underway generation rate is multiplied by the number of days (215 days) spent beyond 12 nm. Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{14,620,000 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{100 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} = 2,440 \text{ hrs/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{2,440 \text{ hrs}}{\text{yr}} \cdot \frac{0.25 \text{ hrs labor}}{2 \text{ hrs}} = 305 \text{ hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{146,200 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{90 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} \cdot \frac{3 \text{ hrs labor}}{\text{hr}} = 81 \text{ hrs labor/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of two WSC-50 centrifuge modules on a CVN 68 Class vessel beyond 12 nm is 386 hrs/yr.

Annually, each WSC-50 requires approximately 20.75 personnel hours of time-based maintenance, 0 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 3-9 and Table 3-10 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for one WSC-50 centrifuge module.

**Table 3-9. WSC-50 Time-Based Maintenance Hours (CVN 68 Class)**

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Change gear case oil.	1	6 months	2
Remove, clean, and grease bowl lock ring, and re-install it.	1	6 months	2
Grease motor bearings.	0.25	See manuf. Recomm.	0.25
Inspect and clean bowl: Remove bowl top. Clean sludge space and disks as required. If the bowl is removed during this procedure, ensure that the spindle cone and bowl nave is clean, dry, and free of grease.	2	3 months	8
Check starting time. Check thickness of clutch shoe linings. Replace as necessary.	0.25	6 months	0.5
Check thickness of brake lining. Replace as necessary.	0.5	12 months	0.5
Check foundation bolts for proper tensioning. Check all readily accessible equipment bolts and fasteners for proper tension.	0.5	12 months	0.5
Check shock mounts for cracks, peeling of rubber, or any distortions. Replace as necessary.	0.25	12 months	0.25

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Check to ensure that a clearance of 3 mm between the decelerator unit and ship's foundation is correct.	0.25	12 months	0.25
Replace ball bearings on spindle	1	12 months	1
Replace ball bearings on worm wheel shaft	1	6 months	2
Check pump strainer. Clean as required.	0.25	6 months	0.5
Check water strainer(s). Clean as required.	0.25	6 months	0.5
Check to make sure operating water feeding device is not plugged.	0.25	6 months	0.5
Check and tighten system hardware including all foundations	1	12 months	1
Check motor winding resistance.	0.5	12 months	0.5
Check operation of pressure switch. Repair or replace as required.	0.25	6 months	0.5
Total Annual Labor per unit			20.75
Total Annual Labor per vessel			41.5

**Table 3-10. WSC-50 Condition-Based Maintenance Hours (CVN 68 Class)**

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 80 operation hours within 12 nm)	Annualized Maintenance Hours (based on 385 operation hours beyond 12 nm)
None	0	0	0	0
Total Annualized Hours	-	-	0	0

Table 3-11 provides the annual labor hours required for WSC 50 Centrifuge.

**Table 3-11. Centrifuge Annual Labor Hours (CVN 68 Class)**

	MPCD Option: WSC-50 Centrifuge
Operator Hours Within 12 nm	71
Operator Hours Beyond 12 nm	386
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	41.5
Total Time	498.5

### **3.2.1.5 Consumables, Repair Parts, and Tools**

Centrifuges require consumables and special tools. However, these requirements do not result in a significant impact. A spare parts kit is available from the vendor. Consumables include items such as filters, gaskets, “O” rings, and bearings. The special tools required are delivered with the device and consist of spanner wrenches made specifically for dismantling the purifier bowl.

### **3.2.1.6 Interface Requirements**

Table 3-12 lists the interfaces required to support each WSC 50 centrifuge module.

**Table 3-12. WSC-50 Interface Requirements (CVN 68 Class)**

Shipboard System	WSC-50 (per unit)
Electrical Power	440VAC/3PH, 80-130kW (107-174 hp)
Compressed Air	0.0045-0.022scfm 0.0058 - 0.029cfm @ 50 psig
Potable Water	50 gpd, 45 psi
Drainage	Gravity drain to OWHT

The CVN 68 is able to support these requirements with no significant impacts on existing systems.

### **3.2.1.7 Control System Requirements**

Centrifuges are pushbutton operated and equipped with programmable logic controls and monitoring systems. The manufacturer recommends that the operator manually turn on the equipment. However, once the centrifuge has reached its operating speed, the WSC-50 does not require constant oversight. It is fully automatic and equipped with an integrated thermostat to control the heater.

A centrifuge may be equipped with an OCM to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than the predetermined desired concentration, the OCM will redirect the effluent back to the OWHT to be reprocessed by the OWS. The oil content monitor alarm can be monitored remotely or locally.

### **3.2.1.8 Other/Unique Characteristics**

No other/unique characteristics have been identified with respect to this MPCD Option Group.

## **3.2.2 Cost Analysis**

The following cost data and calculations are provided to allow the reader to compare relative costs associated with a centrifuge system on a CVN 68 Class vessel.

### 3.2.2.1 Initial Cost

The centrifuge system (i.e., two units) procurement cost is \$904,000 per vessel (Donohue, 2000). Based on ship drawing analysis and a CVN 73 (CVN 68 Class vessel) check, the Alteration and Installation Team (AIT) estimates that installation of the two centrifuge units will cost \$252,000 per vessel (Navy, 2000). The installation would require approximately five weeks to complete. Technical manuals cost approximately \$85,000 (\$9,440 per vessel) to develop a 150-page manual (Gallagher, 1999). The Navy estimates that the development of technical drawings will cost \$33,810 (\$3,757 per vessel). The cost for training material development is approximately \$9,330 (\$1,037 per vessel) (Smith, 2001). The total initial cost for a centrifuge system on a CVN 68 Class vessel is \$1,170,000 per vessel.

### 3.2.2.2 Recurring Cost

#### *Personnel Labor Within 12 nm*

This MPCD requires approximately 113 personnel hours per year for operation, condition-based maintenance, and time-based maintenance within 12 nm, as explained under Section 3.2.1.4 above. The number of annual labor hours multiplied by the \$22.64 hourly MPCD operator labor rate produces the annual labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{113 \text{ hrs labor}}{\text{yr}} = \$2,550/\text{yr (within 12 nm)}$$

#### *Personnel Labor Beyond 12 nm*

This MPCD requires 386 personnel hours per year for operation and condition-based maintenance beyond 12 nm, as explained under Section 3.2.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{386 \text{ hrs labor}}{\text{yr}} = \$8,730/\text{yr (outside 12 nm)}$$

The labor required to transfer waste oil generated by the centrifuge system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose of the waste oil at no charge for these vessels.

Table 3-13 provides annual recurring costs for a centrifuge system on-board a CVN 68 Class vessel.

**Table 3-13. Annual Recurring Costs for Centrifuge Systems (CVN 68 Class)**

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost (\$K)
Within 12 nm	Navy	2.55
Beyond 12 nm	Navy	8.73



### 3.2.2.3 Total Ownership Cost (TOC)

Table 3-14 summarizes the TOC and annualized cost over a 15-year lifecycle for a centrifuge system on a CVN 68 Class vessel.

**Table 3-14. TOC for Centrifuge Systems (CVN 68 Class)**

<b>Cost (\$K)</b>	<b>Vessel Operation Within 12 nm</b>	<b>Vessel Operation Within + Beyond 12 nm</b>
Total Initial	1170	1170
Total Recurring	28.4	97
TOC (15-yr lifecycle)	1200	1270
Annualized	102	108

## 3.3 COLLECTION, HOLDING, TRANSFER (CHT)

The following sections discuss the feasibility and cost impacts of not discharging bilgewater (treated or untreated) from CVN 68 Class vessels to the environment within 12 nm from shore. This no-discharge option is referred to as the practice of CHT of bilgewater within 12 nm. The bilgewater may be transferred to shore facilities (including tanks, barges, and trucks) in port or discharged overboard in accordance with applicable regulations beyond 12 nm.

### 3.3.1 Practicability and Operational Impact Analysis – Existing Vessels

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of practicing CHT.

#### 3.3.1.1 Space and Weight

CVN 68 Class vessels are equipped with a series of oily waste holding tanks (OWHTs) that have a combined design capacity of approximately 42,000 gallons. The holding tanks are designed with capacity 5-10 percent in excess of the ship's requirements, to minimize the risk of overfilling the tanks, which would result in spillage. These tanks are designed to collect and hold oily waste (i.e., bilgewater) for processing by the vessel's 50-gpm OWS units or for transfer to shore, as applicable. As such, CVN 68 Class vessels are capable of practicing CHT up to the existing holding capacity without experiencing any impacts to space and weight. The potential for exceeding the vessel's existing space and weight capacities, as a result of practicing CHT, will depend upon the length of time spent within 12 nm from shore and whether the port visited has the capability to offload wastewater.

During a typical five-year operating cycle, CVN 68 Class vessels may visit many ports for varying lengths of time. The longest stays (i.e., 30 days or more) in port tend to be at the vessel's homeport or at other major naval ports, where full shore services, including wastewater offloading, are available. During these visits, CVN 68 Class vessels typically do not operate their OWS units, but instead transfer their bilgewater to shore facilities. However, to support their operational requirements (e.g., search and recovery missions), CVN 68 Class vessels may occasionally visit smaller non-Navy ports where offloading services are not available. In this

situation, a CVN 68 Class vessel could be required to collect and hold all bilgewater generated until the ship is beyond 12 nm. The following paragraphs describe these two potential scenarios: (1) arriving at a port where wastewater offloading services are available, and (2) arriving at a port where such services are not available.

*Ports with wastewater offloading services:* CVN 68 Class vessels are homeported in Norfolk, VA; San Diego, CA; and Bremerton and Everett, WA. These are major Naval ports with complete shore services, including wastewater offloading. Once a vessel has tied up pierside at one of these ports, bilgewater can be transferred as needed. CVN 68 Class vessels can also collect and hold bilgewater generated while transiting from 12 nm to port for transfer shoreside. Of the four Naval ports listed, the transit to Bremerton represents the most extreme case for time in transit between 12 nm and port, which can take up to six hours. While underway, CVN 68 Class vessels generate approximately 68,000 gallons per day of bilgewater, or 2,800 gallons per hour. Using a generation rate of 2,800 gallons per hour over 6 hours, the maximum volume of bilgewater generated would be approximately 20,000 gallons. Transits to ports other than Bremerton or Everett, WA, will take less time and result in lower volumes of bilgewater generation. Once in port, CVN 68 Class vessels can transfer their bilgewater to shore as needed. Since the 20,000 gallons collected during transit is well within the holding capacity for CVN 68 Class vessels, practicing CHT while transiting to or from a port where shore offloading facilities are available will have no space or weight impacts.

*Ports without wastewater offloading services:* If CVN 68 Class vessels are visiting a port where offloading bilgewater is not possible, the ship could be required to hold all bilgewater during the entire time spent within 12 nm. A typical visit to a small port may last two to five days. Assuming a five-day port visit, a CVN would generate approximately 85,000 gallons of bilgewater (based on in port generation rate). Using a generation rate of 2,800 gallons per hour and a total transit time of 6 hours (3 hours in each direction), the aircraft carrier would generate an additional 17,000 gallons of bilgewater while transiting to and from port. The total bilgewater generated within 12 nm from shore would be 102,000 gallons. This is more than twice the current safe holding capacity, and would result in space and weight impacts. Under this scenario, a CVN 68 Class vessel would be limited to practicing CHT for less than two days without exceeding its design holding capacity.

The practice of CHT within the existing holding capacity will not result in any space and weight impacts. While the above analyses describe typical operating scenarios, there may be situations where practicing CHT may exceed the vessel's existing holding capacity. Extra tank capacity would be required to accommodate any additional volume of bilgewater collected. Because most, if not all, space and weight allocations on CVN 68 Class vessels are tightly controlled, and because space is limited, there is generally very little unassigned space to which additional tankage can be added. Therefore, the most likely strategy for increasing bilgewater holding capacity would be to convert other existing tanks to bilgewater holding tanks. However, converting existing tank space to hold bilgewater will likely result in impacts to those systems or services that rely on the tanks that would be converted for holding oily waste.

### **3.3.1.2 Personnel/Equipment Safety**

Practicing CHT within the vessel's existing holding capacity will not pose any additional safety hazards to the vessel's crew or equipment.

### **3.3.1.3 Mission Capabilities**

Practicing CHT within the vessel's existing holding capacity will not have an impact on ship's signature, war-fighting capabilities, mobility, or on any mission critical systems or operations.

The ship designers review the ship's requirements (e.g., vessel's range, the number of crew, etc.) to determine what tank capacities are needed to allow the ship to fulfill its mission. With the exception of approximately five percent excess capacity as a margin of safety, ship designers do not size a vessel's tank capacity beyond what is necessary to meet the ship's requirements. Practicing CHT in excess of the vessel's existing holding capacity would likely require that additional tanks be built or tanks used for other purposes be converted to bilgewater holding tanks. Reducing the capacity of existing tanks such as aviation fuel (JP-5) tanks, potable water tanks, or sewage tanks, will reduce the ship's current capability to support its mission.

### **3.3.1.4 Personnel Impact**

Practicing CHT within the vessel's existing holding capacity will not result in any personnel impacts other than time required to oversee the transfer of bilgewater and oily waste to shore (see analysis below).

Practicing CHT as a primary control option does not require special training. Manning is required to oversee the transfer of bilgewater to a shore facility (i.e., operate the oily waste transfer (OWT) pump and associated valves/hull connections). This transfer requires three workers per event as described in the Section 3.1.1.4.

A CVN 68 Class vessel generates approximately 2,703,000 gallons of bilgewater annually within 12 nm. The annual volume of bilgewater generated within 12 nm of shore divided by the OWT pump rate of 180 gpm, multiplied by the number (three) of crewmembers required for oversight, equals the personnel hours required per year for CHT on a CVN 68 Class vessel.

$$\frac{2,703,000 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{180 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} \cdot \frac{3 \text{ hours labor}}{\text{hr}} = 750 \text{ hrs labor/yr}$$

Table 3-15 provides the annual labor hours required for CHT.

**Table 3-15. CHT Annual Labor Hours (CVN 68 Class)**

	MPCD Option: CHT
Operator Hours Within 12 nm	750
Operator Hours Beyond 12 nm	0
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	0
Total Time	750

### **3.3.1.5 Consumables, Repair Parts, and Tools**

There are no requirements for consumables, repair parts, or tools associated with CHT.

### **3.3.1.6 Interface Requirements**

Practicing CHT does not require any unique interface requirements. OWT pumps and associated valves, piping, and hull connections exist on this vessel class to support the current practice of shoreside disposal.

### **3.3.1.7 Control System Requirements**

There are no automated control system requirements associated with CHT. However, crewmembers are required by OPNAVINST 5090.1 (series) to watch for oily wastewater spills (e.g., during shoreside transfers) (Navy, 2002).

### **3.3.1.8 Other/Unique Characteristics**

No other/unique characteristics have been identified with respect to this MPCD Option Group.

## **3.3.2 Cost Analysis – Existing Vessels**

The following cost data and calculations are provided to allow the reader to compare relative costs associated with practicing CHT on a CVN 68 Class vessel. CHT is not practiced beyond 12 nm from shore; therefore, CHT costs are calculated for operation within 12nm only. Vessels in this class will continue to comply with appropriate regulations beyond 12 nm.

### **3.3.2.1 Initial Cost**

As described in Section 3.3.1.3, the reallocation of tank space to increase bilgewater holding capacity on a CVN 68 Class vessel would result in impacts on mission capabilities and personnel. For the cost analysis, it was assumed that bilgewater holding capacity is adequate. Therefore, the initial cost of acquisition and installation of additional equipment such as tankage and piping systems is assumed to be zero.

### 3.3.2.2 Recurring Cost

CVN 68 Class vessels generate 2,703,000 gal of bilgewater within 12 nm annually and require 750 personnel hours per year for CHT manning, as explained under Section 3.3.1.4. The annual labor hours multiplied by the \$22.64 per hour MPCD operator labor rate produces the annual recurring labor cost of \$17,000.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{750 \text{ hrs labor}}{\text{yr}} = \$17,000/\text{yr}$$

The annual bilgewater generation rate within 12 nm is 2,703,000 gallons. The annual bilgewater generated annually within 12 nm multiplied by the oily waste disposal unit cost produces the annual recurring disposal cost for CHT on a CVN 68 Class vessel of \$202,500.

$$\frac{2,703,000 \text{ gal}}{\text{yr}} \bullet \frac{\$0.0749}{\text{gal}} = \$202,500/\text{yr}$$

There are no other Armed Forces vessels within the CVN 68 vessel grouping; therefore annual recurring costs were not calculated using other Armed Forces (e.g., Coast Guard) waste disposal figures.

Table 3-16 provides annual recurring costs for CHT on-board a CVN 68 Class vessel.

**Table 3-16. Annual Recurring Costs for CHT (CVN 68 Class)**

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost (\$K)
Within 12 nm	Navy	219.5
Beyond 12 nm	Navy	0

### 3.3.2.3 Total Ownership Cost (TOC)

Table 3-17 summarizes the TOC and annualized cost over a 15-year lifecycle of practicing CHT on a CVN 68 Class vessel.

**Table 3-17. TOC for CHT (CVN 68 Class)**

Cost (\$K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	0	0
Total Recurring	2440	2440
TOC (15-yr lifecycle)	2440	2440
Annualized	207	207

### **3.3.3 Practicability and Operational Impact Analysis – New Design Vessels**

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of practicing CHT on new design vessels.

#### **3.3.3.1 *Space and Weight***

Ports with wastewater offloading services: As discussed in Section 3.3.1.1, practicing CHT while tied up pierside or transiting to or from a port where shore offloading facilities are available (assuming a total maximum transit time of six hours) will have no space or weight impacts.

Ports without wastewater offloading services: As discussed in Section 3.3.1.1, the current holding capacity of the OWHT (42,000 gallons) is not sufficient to hold all bilgewater generated during an extended port visit (typically two to five days) at a port where shore offloading facilities are not available. Based on typical operating scenarios and bilgewater generation rates, NSWCCD Code 20 determined that a tank (or series of tanks) with a capacity of approximately 112,000 gallons would be required to hold all bilgewater generated during an extended port visit. This is approximately three times greater than the existing OWHT capacity and is a 1.49 percent increase in total dead weight. To support this additional tank volume, the size of the ship must be increased. Increasing the ship's size to support this additional dead weight will require approximately 530 long tons (LT) of additional structure, resulting in a total weight increase of approximately 799 LT and approximately 10 ft in overall ship length. This increase represents a 1 percent increase in full load weight over a current CVN 68 Class vessel. Furthermore, the additional structure required to accommodate a larger CHT system would increase the ship's volume by approximately 144,000 ft<sup>3</sup>, of which only 9,300 ft<sup>3</sup> (approximately 6.2 percent) would be occupied by the CHT system (Navy, 2003a).

#### **3.3.3.2 *Personnel/Equipment Safety***

Practicing CHT within the vessel's designed holding capacity on new design vessels will not pose any safety hazards to vessel equipment or crew.

#### **3.3.3.3 *Mission Capabilities***

Practicing CHT within the vessel's designed holding capacity will not impact the mission-related operational capability of Navy vessels (Navy, 2003a).

#### **3.3.3.4 *Personnel Impact***

Practicing CHT would require approximately three crewmembers per event to conduct the transfer of oily waste to shoreside facilities. Practicing CHT on new design vessels is expected to require 750 total hours of labor per year (Navy, 2003a).

#### **3.3.3.5 *Consumables, Repair Parts, and Tools***

There are no requirements for consumables, repair parts, and tools associated with practicing CHT on new design vessels.

### **3.3.3.6 Interface Requirements**

Practicing CHT on new design vessels will not have an impact on interface requirements. No additional load would be placed on the ship's electrical plant (Navy, 2003a).

### **3.3.3.7 Control System Requirements**

There are no automated control system requirements associated with CHT. However, crewmembers are required by OPNAVINST 5090.1 (series) to watch for oily wastewater spills (e.g., during shoreside transfers) (Navy, 2002).

### **3.3.3.8 Other/Unique Characteristics**

No other/unique characteristics have been identified with respect to practicing CHT on new design vessels.

## **3.3.4 Cost Analysis – New Design Vessels**

The following cost data and calculations are provided to allow the reader to compare relative costs associated with practicing CHT on a new design vessel in this vessel group. CHT is generally not practiced beyond 12 nm from shore; therefore, CHT costs are calculated for operations within 12 nm only. Vessels in this class must continue to comply with appropriate regulations when operating beyond 12 nm.

NSWCCD Code 20 estimated the total initial, total recurring, TOC, and annualized costs for practicing CHT on new design vessels in this vessel group. Those costs are summarized in Table 3-18 below. Code 20 concluded that the additional cost and increase in ship size required by a larger CHT system is not recommended for a system considered to be non-mission critical (Navy, 2003a).

### **3.3.4.1 Initial Cost**

The required increase in OWHT volume (112,000 gallons vs. 42,000 gallons) would require new design vessels in this vessel group to add 530 LTs of additional steel, adding approximately \$27 million to the initial acquisition cost of each ship (Navy, 2003a).

### **3.3.4.2 Recurring Cost**

Practicing CHT requires 750 total labor hours per year for operation, as explained in the Section 3.3.3.4. The labor and disposal costs associated with bilgewater disposal are estimated to be \$220,000 annually for the Navy (Navy, 2003a).

### **3.3.4.3 Total Ownership Cost (TOC)**

Table 3-18 summarizes the TOC and annualized cost of practicing CHT on a CVN 68 Class vessel.

**Table 3-18. TOC for CHT System on New Design Vessels (CVN 68 Class)**

<b>(\$K)</b>	<b>Vessel Operation Within 12 nm</b>	<b>Vessel Operation Within + Beyond 12 nm</b>
Total Initial	27,000	27,000
Total Recurring	2,400	2,400
TOC (15-yr lifecycle)	29,000	29,000
Annualized	2,500	2,500

### 3.4 EVAPORATION

Commercial evaporation units are designed to operate with freshwater waste streams (Navy and EPA, 2000b). To apply evaporation technology in a saltwater environment, design concerns, such as corrosivity, plating-out of salt in the unit, and buildup of sludge would need to be addressed before this technology could be considered feasible on this vessel class. The following analysis is provided to further describe the feasibility of this MPCD.

As stated in Section 3.0, CVN 68 Class vessels are equipped with two 50-gpm-gravity coalescer OWSs. Operating this MPCD in batch mode (i.e., operating at maximum capability to eliminate accumulating bilgewater) minimizes the impact on the vessel's crew. A bilgewater evaporator with the maximum available processing rate, one gallon per minute, was chosen for this analysis to minimize the number of units required to meet the current MPCD processing rate. A total of 100 evaporation units, each requiring 162 kW of electrical power to operate, would be required to meet the current processing rate. CVN 68 Class vessels have a total electrical capacity of 32,000 kW and a designed operating capacity of 21,600 kW. The designed operating capacity is based on the assumption that one ship service generator is out of service and the remaining generators are operating at 90 percent capacity (Navy, 1980). The designed operating capacity includes a 20 percent service life margin (6,254 kW) to support the addition of electrical equipment throughout the vessel's lifecycle (Navy, 1980). The service life margin represents the total electrical capacity available to support additional electrical equipment that may be installed following initial construction. The use of evaporators would constitute a total electrical load of 16,200 kW, which is greater than the 6,254 kW service life margin available.

A significant amount of electrical power is required by Armed Forces vessels to support mission-related payloads, such as the combat systems (e.g., weapons, command, communications, control, electronic warfare and countermeasures, etc.) and combat support and supply systems. Because the use of evaporators would exceed the vessel's service life margin, mission essential electrical equipment would have to be shut off while running the evaporators. This equipment is essential for vessel safety and defense. Not operating this equipment while running the evaporators would leave the vessel vulnerable to safety hazards (e.g., collisions) and potential military threats. Furthermore, despite the flexibility afforded by new design vessels (e.g., reduced cost of forward-fit installation), new design vessels are not expected to be able to support the evaporators' substantial power requirements. Therefore, based on the evaporators' power requirements that subsequently degrade the vessel's mission and safety capabilities, evaporation is not a feasible MPCD option group for either existing or new design vessels represented by the CVN 68 Class. In addition, design issues such as corrosivity, plating out of



salt in the unit, and buildup of salt and sludge still need to be addressed before this technology may be feasible on this vessel class.

### 3.5 HYDROCYCLONES

The following sections discuss the feasibility and cost impacts of installing and operating a hydrocyclone on-board a CVN 68 Class vessel.

#### 3.5.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of a hydrocyclone unit.

##### 3.5.1.1 Space and Weight

A single 100-gpm hydrocyclone system is being proposed in this analysis. This model was chosen because it has equivalent processing capacity as the current MPCDs installed on CVN 68 Class vessels. A single 100-gpm unit was chosen rather than two 50-gpm units. Because the 50-gpm unit and the 100-gpm unit are the same with the exception of the feed pump rate, using two 50-gpm hydrocyclone units versus a single 100-gpm unit would unnecessarily double the space and weight impacts of the MPCD. The hydrocyclone units are custom engineered and can be made to accommodate the desired flow rate. The hydrocyclone assembly is normally oriented horizontally, but could be oriented vertically if necessitated by space requirements. Table 3-19 provides the space and weight for a 100-gpm skid mounted model consisting of a strainer basket, helical rotor pump, 12 inch diameter vessel, and interconnecting piping.

**Table 3-19. Hydrocyclone Specifications (CVN 68 Class)**

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft <sup>3</sup> )	Weight (lbs.) Dry/Flooded
Per unit	1	100 gpm	7 x 6 x 4	10 x 8 x 6	168	900/1000
Total (To achieve required processing capacity)	1	100 gpm	7 x 6 x 4	10 x 8 x 6	168	900/1000

Hydrocyclone units are designed for single-deck operation and would be installed in the current OWS room. The two existing OWSs would be removed and replaced with a single hydrocyclone unit in the same location.

##### 3.5.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with hydrocyclones. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While hydrocyclones require electrical power, standard shipboard safety procedures for handling electrical equipment should be adequate.

### 3.5.1.3 Mission Capabilities

The installation and operation of hydrocyclones on CVN 68 Class vessels are not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

### 3.5.1.4 Personnel Impact

The hydrocyclone system runs in automatic mode, but requires general supervision while the unit is operating. Based on a bilgewater processing rate of 100 gpm and approximately 2,703,000 gallons of bilgewater generated annually within 12 nm, the number of hours the hydrocyclone is operated annually within 12 nm is 450 hours.

$$\frac{2,703,000 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{100 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} = 450 \text{ hrs/yr}$$

The labor requirement for general oversight of the hydrocyclone was calculated as 0.25 hours (15 minutes) for every two hours of operation. The supervisory labor requirement of 15 minutes for every two hours of operation is based on the assumption that although the unit is automatic, a crewmember will be assigned to general oversight of multiple pieces of equipment at once. Therefore, based on the annual operating requirement of 450 hours, the annual labor requirement associated with the operation of the hydrocyclone within 12 nm is 56 hours, as calculated below:

$$\frac{450 \text{ hrs operation}}{\text{yr}} \cdot \frac{0.25 \text{ hr labor}}{2 \text{ hrs operation}} = 56 \text{ hrs labor/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires three crewmembers per event as described under Section 3.1.1.4. The labor hours associated with transferring the waste oil produced within 12 nm from shore by the hydrocyclone on CVN 68 Class carriers are calculated by dividing the waste oil volume (1 percent of the annual bilgewater volume generated while operating within 12 nm) by the waste oil pump rate (90 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{27,030 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{90 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} \cdot \frac{3 \text{ hrs labor}}{\text{hr}} = 15 \text{ hrs labor/yr}$$

The combined annual labor associated with the operational oversight of the hydrocyclone unit within 12 nm and transfer of waste oil generated within 12 nm on a CVN 68 Class vessel is 71 hours.

The total labor requirement associated with vessel operations beyond 12 nm includes MPCD operator oversight (i.e., 15 minutes for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore attributable to vessel operation beyond 12 nm. The annual labor requirement associated with operating this MPCD beyond 12 nm is calculated using the same methodology used to calculate the annual labor requirement within 12 nm. The approximate volume (i.e., 14,620,000 gal) of bilgewater generated beyond 12 nm and

resultant volume (i.e., 146,200 gal) of waste oil that requires offloading to shore are based on the CVN 68 Class vessel underway bilgewater generation rate of 68,000 gpd. The underway generation rate is multiplied by the number of days (215 days) spent beyond 12 nm. Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{14,620,000 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{100 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} = 2,440 \text{ hrs/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{2,440 \text{ hrs}}{\text{yr}} \cdot \frac{0.25 \text{ hrs labor}}{2 \text{ hrs}} = 305 \text{ hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{146,200 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{90 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} \cdot \frac{3 \text{ hrs labor}}{\text{hr}} = 81 \text{ hrs labor/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of the hydrocyclone system on a CVN 68 Class vessel beyond 12 nm is 386 hrs/yr.

Annually, the hydrocyclone requires approximately 7.8 personnel hours of time-based maintenance, 0 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 3-20 and Table 3-21 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for a hydrocyclone unit.

**Table 3-20. Hydrocyclone Time-Based Maintenance Hours (CVN 68 Class)**

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Clean and Inspect Strainer Basket	0.25	1 to 3 months	1
Open and Inspect Hydrocyclone Bundle	2	12 months	2
Inspect Positive Displacement Pump for Wear	1	18 months	0.8
Rebuild Positive Displacement Pump Rotors	10	18 to 36 months	4
Total Annual Labor per unit	-	-	7.8
Total Annual Labor per vessel	-	-	7.8

**Table 3-21. Hydrocyclone Condition-Based Maintenance Hours (CVN 68 Class)**

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 451 operation hours within 12 nm)	Annualized Maintenance Hours (based on 2440 operation hours beyond 12 nm)
None	0	0	0	0
Total Annualized Hours	-	-	0	0

Table 3-22 provides the annual labor hours required to operate and maintain a hydrocyclone module.

**Table 3-22. Hydrocyclone Annual Labor Hours (CVN 68 Class)**

	MPCD Option: Hydrocyclone
Operator Hours Within 12 nm	71
Operator Hours Beyond 12 nm	386
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	7.8
Total Time	465

Hydrocyclones do not have an impact on habitability. Hydrocyclones are closed systems, so no vapors are present. Manning requirements will be minimal because the hydrocyclones require very little maintenance, and operation can be fully automated. Periodic monitoring of the inlet and underflow pressures would be recommended to evaluate operating conditions and determine if maintenance is needed.

### **3.5.1.5 Consumables, Repair Parts, and Tools**

Consumables and repair parts, which should be on hand, include “O” rings and gaskets for the cyclone vessel, a few spare cyclone liners, and some components (e.g., spare diaphragm) for the pump.

### **3.5.1.6 Interface Requirements**

Table 3-23 summarizes the specific system interface requirements associated with the hydrocyclones.

**Table 3-23. Hydrocyclone Interface Requirements (CVN 68 Class)**

Shipboard System	100-gpm unit
Electrical Power	3.7 kW (5 hp), 460VAC, 3 Phase, 60 Hz

The CVN 68 Class vessel is able to accommodate this interface requirement.

### ***3.5.1.7 Control System Requirements***

Hydrocyclones are designed to operate in either automatic or manual mode. Automatic operation is the normal operating mode. When placed in the automatic mode, activation of the units is controlled by tank level switches installed in the OWHT. When the volume of the liquid reaches a pre-set level, one level switch will start the unit(s). When the liquid level in the OWHT drops to a pre-set level, a second level switch signals the unit(s) to shut down. Units have a flow sensor that will shut down the system if the pump loses suction, and a remote alarm/indicator panel. This feature allows shipboard personnel to monitor the operating status of the units while in the automatic mode of operation.

A hydrocyclone may be equipped with an oil content monitor (OCM) to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than the predetermined desired concentration, the OCM will redirect the effluent back to the OWHT to be processed again by the OWS.

### ***3.5.1.8 Other/Unique Characteristics***

No other/unique characteristics have been identified with respect to this MPCD option.

## **3.5.2 Cost Analysis**

The following cost data and calculations are provided to allow the reader to compare relative costs associated with a hydrocyclone system on a CVN 68 Class vessel.

### ***3.5.2.1 Initial Cost***

The hydrocyclone system (i.e., one unit) procurement cost is \$62,000 (Benjamin, 2000). Installation cost includes the cost of labor, materials, and oversight to install the unit. Based on drawing analysis and a CVN 73 (CVN 68 Class vessel) ship check, the Navy estimates that installation of the 100-gpm hydrocyclone unit would cost \$148,200 per vessel (Navy, 2000). To install the hydrocyclone, the two existing gravity coalescence units must first be removed from the OWS room in order to make space available for the hydrocyclone system. The installation would require approximately four weeks to complete. Technical manuals cost approximately \$85,000 (\$9,440 per vessel) to develop a 150-page manual (Gallagher, 1999). The Navy estimates that the development of technical drawings will cost \$28,010 (\$3,113 per vessel) (Navy, 2000). The cost for training materials is approximately \$9,330 (\$1,037 per vessel) (Smith, 2001). The initial cost of a hydrocyclone system on a CVN 68 Class vessel is \$224,000 per vessel.

### 3.5.2.2 Recurring Costs

#### *Personnel Labor Within 12 nm*

This MPCD requires 79 personnel hours per year for operation, condition-based maintenance, and time-based maintenance within 12 nm, as explained under Section 3.5.1.4. The number of annual labor hours multiplied by the \$22.64 hourly MPCD operator labor rate produces the annual labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{79 \text{ hrs labor}}{\text{yr}} = \$1,800/\text{yr}$$

#### *Personnel Labor Beyond 12 nm*

This MPCD requires 386 personnel hours per year for operation, and conditioned based maintenance beyond 12 nm, as explained under Section 3.5.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{386 \text{ hrs labor}}{\text{yr}} = \$8,730/\text{yr}$$

The labor required to transfer waste oil generated by the hydrocyclone system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose the waste oil at no charge for these vessels.

Table 3-24 provides annual recurring costs for a hydrocyclone system on-board a CVN 68 Class vessel.

**Table 3-24. Annual Recurring Costs for Hydrocyclone (CVN 68 Class)**

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost (\$K)
Within 12 nm	Navy	1.8
Beyond 12 nm	Navy	8.73

### 3.5.2.3 Total Ownership Cost (TOC)

Table 3-25 summarizes the TOC and annualized cost over a 15-year lifecycle for a hydrocyclone system on a CVN 68 Class vessel.

**Table 3-25. TOC for Hydrocyclone (CVN 68 Class)**

<b>Cost (\$K)</b>	<b>Vessel Operation Within 12 nm</b>	<b>Vessel Operation Within + Beyond 12 nm</b>
Total Initial	224	224
Total Recurring	20	91.4
TOC (15-yr lifecycle)	244	321
Annualized	20.7	27.3

### **3.6 *IN SITU* BIOLOGICAL TREATMENT**

*In situ* biological treatment of bilgewater is the addition of microbes to a vessel's bilge spaces to digest the oil content of the bilgewater. For *in situ* biological treatment to be effective, the microbes must be left in the bilge for a sufficient period of time to digest the bilgewater's oil content. According to the vendor, the most effective use of *in situ* biological treatment for the wastewater that accumulates in the bilge is to leave the *in situ* material in the bilge spaces on the vessel for a 30-day period to establish a population of microbes (Opsanick, 2000). Transferring bilgewater to shore or allowing additional bilgewater to be introduced to the bilge spaces before the 30-day period is complete may decrease the *in situ* biological treatment's effectiveness. Due to the lack of performance data, the extent to which the effectiveness of biological treatment would be decreased cannot be determined (Opsanick, 2000). However, the vessel would be continuously generating bilgewater during this period, disrupting the batch processing method recommended by the manufacturer. Furthermore, the vessel's total bilgewater generation over a 30-day period is at least 500,000 gallons. Leaving this volume of bilgewater in the bilge spaces to allow more complete treatment would inhibit the safe operation of existing or new design vessels. Therefore, *in situ* biological treatment is not feasible for existing or new design vessels represented by CVN 68 Class vessels.

### **3.7 OIL ABSORBING SOCKS (OASS)**

OASSs are designed to absorb oil floating on the surface of a body of water (Sorbent Products, Inc., 2000). In this application, OASSs would be placed inside the bilge areas of a CVN 68 Class vessel to continuously absorb the waste oil from the bilgewater. When the OASSs become fully saturated, they are manually removed and replaced with new OASSs. This use of OASSs for CVN 68 Class vessels poses a concern regarding the generation of solid waste, a potential to effect emergency dewatering, and a potential fuel source for a fire.

The use of OASSs for CVN 68 Class vessels will result in the generation of a large amount of solid waste. As noted earlier, CVN 68 Class vessels generate approximately 170 gallons of waste oil per day while in port and 680 gallons per day while underway. The density of a saturated OAS is approximately 7.3 pounds per gallon of waste oil (Ergon Environmental Products Inc., 1998). OASSs are solid media that trap and hold waste oil, a liquid. Therefore, using OASSs would generate approximately 1,200 pounds of solid waste per day while in port. If used underway, OASSs would generate approximately 5,000 pounds of solid waste per day. The removal of saturated OASSs would require a high level of manual effort (i.e., labor provided by the ship's crew). The saturated OASSs would need to be removed from the bilge and carried up from the lower decks of the vessel so they could be transferred to shore. By comparison, waste

oil captured by the current MPCD option (i.e., the gravity coalescing OWS) remains a liquid waste stream and would only require a few minutes to pump the same amount ashore.

The presence of OASs in the bilge spaces would potentially restrict the flow of bilgewater through normal and emergency dewatering pumps and strainers by clogging the suction points. The use of OASs in the bilge spaces of Navy vessels would not be feasible due to vessel safety and survivability concerns. The Navy presently prohibits (through practice) the presence of any loose materials or debris in the bilge areas that could potentially interfere with normal or emergency dewatering activities. Securing the OASs to a pipe or other type of fixture in the bilge is not feasible because the force of a shock or explosion would potentially dislodge the OAS. Furthermore, as the OAS absorbs oil it becomes a concentrated fuel source for a fire.

Based on the potential operational and safety impacts related to solid waste handling, emergency dewatering, and potential fire hazards, OASs are not a feasible MPCD option group for the CVN 68 Class vessel group. New design vessels cannot resolve these impacts.

### **3.8 FILTER MEDIA**

The following sections discuss the feasibility and cost impacts of installing and operating a filter media unit on a CVN 68 Class vessel. The polishing unit consists of oil absorbing filter media canisters and is designed to treat OWS effluent before being discharged overboard. Although primary OWSs installed on-board CVN 68 Class vessels generally have a combined processing rate of approximately 100 gpm, due to space constraints, the Navy is planning to install filter media capable of handling approximately 50 gpm on-board CVN 68 Class vessels. The 50-gpm filter media system was selected as a secondary MPCD on the basis of size and its ability to match the capacity requirements of the current MPCD. The Navy expects this capacity to be sufficient for processing the amount of bilgewater generated within 12 nm where an effluent with low oil concentration is most critical. Once beyond 12 nm, the vessel could operate its primary OWS and continue to operate in compliance with regulatory requirements.

#### **3.8.1 Practicability and Operational Impact Analysis – Existing Vessels**

Filter media polishing units consist of oil absorbing filter media and are designed to treat OWS effluent before it is discharged overboard. This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of filter media secondary OWS systems.

##### **3.8.1.1 *Space and Weight***

In order to process 50 gpm of OWS effluent on a CVN 68 Class vessel, five 10-gpm filter media polisher units can be connected in parallel. Each filter media polisher contains 9 media canisters (45 canisters total). The cylindrical canisters can be stacked and have a height of 13 inches and a diameter of 12 inches. On the representative vessel, an existing workbench will be required to be removed and some minor piping and equipment will require relocation to provide space for the five 10-gpm filter media polisher units in the existing OWS room (Navy, 2000). Alterations on a similar scale would need to be performed on the other vessels in this group. Table 3-26 provides the approximate space and weight of these 10 gpm units.



**Table 3-26. OWS Filter Media Polisher Physical Data (CVN 68 Class)**

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft <sup>3</sup> )	Weight (lbs.) Dry/Flooded
Per unit	1	10 gpm	4 x 1.3 x 3.25	5.6 x 2.8 x 5.25	18	730/1675
Total (To achieve required processing capacity)	5	50 gpm	-	-	87	3650/8375

### 3.8.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with this MPCD. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material.

### 3.8.1.3 Mission Capabilities

The installation and operation of this MPCD on CVN 68 Class vessels is not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

### 3.8.1.4 Personnel Impact

OWS filter media polisher systems run in automatic mode, but require general supervision while the unit is operating. It is assumed that because a secondary OWS unit runs in conjunction with a primary OWS unit, the secondary units will not require significant additional oversight. Therefore, operator oversight hours associated with secondary units are assumed to be zero.

The recovered waste oil is absorbed into filter media canisters that must be offloaded. The time required to replace the filter media canisters is one hour for each unit, for a total of five hours for all five units. The filter media canisters must be replaced after approximately 400 hours of operation (Galecki, 2000). With a total processing rate of 50 gpm and a total of 2,676,000 gallons of effluent to be processed annually (equal to bilgewater generated annually within 12 nm minus 1 percent of oil removed by primary OWS), the filter media will have to operate approximately 892 hours per year to process the bilgewater generated within 12 nm. Therefore, the filter media will have to be replaced every 5.4 months. The annual number of hours spent replacing the filter media canisters is 11 hours per year.

$$\frac{2,676,000 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{50 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} \cdot \frac{5 \text{ hrs labor}}{400 \text{ hrs}} = 11 \text{ hrs labor/yr}$$

The storage of spare canisters and the offloading of expended canisters will not impose a significant impact to the vessel's crew and will not be considered here or in the Cost Analysis section.

Annually, the filter media canisters require approximately 0 personnel hours of time-based maintenance, 11 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 3-27 and Table 3-28 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for a filter media unit. Table 3-29 provides the annual labor hours required to operate and maintain the proposed MPCD discussed in this section.

**Table 3-27. Filter Media Time-Based Maintenance (CVN 68 Class)**

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
None	0	0	0
Total Annual Labor per unit			0
Total Annual Labor per vessel			0

**Table 3-28. Filter Media Condition-Based Maintenance Hours (CVN 68 Class)**

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 892 operation hours within 12 nm)	Annualized Maintenance Hours (based on 0 operation hours beyond 12 nm)
Replace Filter Media Canisters	5	400	11	0
Total Annualized Hours	-	-	11	0

**Table 3-29. Filter Media Annual Labor Hours (CVN 68 Class)**

	MPCD Option: Filter Media
Operator Hours Within 12 nm	0
Operator Hours Beyond 12 nm	0
Condition-based Maintenance Within 12 nm	11
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	0
Total Time	11

### **3.8.1.5 Consumables, Repair Parts, and Tools**

The OWS filter media polishing unit requires the replacement of 45 filter media canisters (9 canisters per unit times 5 units). The canisters may be stored on the vessel or shoreside. Filter media canisters are considered spent if the pressure drop across the polisher unit exceeds 12 psi. No special repair parts or tools are required for the operation or maintenance of these units.

### **3.8.1.6 Interface Requirements**

No specific system interface requirements are associated with the OWS filter media polishing system.

### **3.8.1.7 Control System Requirements**

The OWS filter media polishing system operates automatically in response to the primary OWS operation. Therefore, the polisher unit does not have any unique control system requirements.

### **3.8.1.8 Other/Unique Characteristics**

No other/unique characteristics have been identified with respect to this MPCD option.

## **3.8.2 Cost Analysis – Existing Vessels**

The following cost data and calculations are provided to allow the reader to compare relative costs associated with using and installing the filter media MPCD on a CVN 68 Class vessel.

### **3.8.2.1 Initial Cost**

The filter media system procurement cost is \$15,600 per unit, or \$78,000 per system (i.e., five units) (Hanrahan, 1997). Based on ship drawing analysis and a CVN 73 (CVN 68 Class vessel) ship check, the Navy estimates that installation of the filter media on a CVN 68 Class vessel would cost \$116,900 per vessel (Navy, 2000). The unit would be installed in the OWS room, where the existing workbench and minor piping and equipment relocations would be required to make space available. The installation would require approximately four weeks to complete. Technical manuals cost approximately \$85,000 (\$9,444 per vessel) to develop a 150-page manual (Gallagher, 1999). The development of technical drawings will cost \$16,420 (\$1,825 per vessel) (Navy, 2000). The cost for training materials is approximately \$9,330 (\$1,037 per vessel) (Smith, 2001). The total initial cost of a filter media system on a CVN 68 Class vessel is \$208,000 per vessel.

### **3.8.2.2 Recurring Cost**

This MPCD requires 11 personnel hours per year for condition-based maintenance within 12 nm, as explained under Section 3.8.1.4. The number of annual labor hours multiplied by the \$22.64 hourly MPCD operator labor rate produces the annual labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{11 \text{ hrs labor}}{\text{yr}} = \$250/\text{yr (within 12 nm)}$$

The replacement cost of filter media canisters is \$7,000/unit. Because this vessel class requires 5 units, the cost for canister consumables at each replacement interval is \$35,000. The filter media canisters must be replaced after approximately 400 hours of operation (Galecki, 2000). With a total processing rate of 50 gpm and a total of 2,676,000 gallons of effluent to be processed

annually, the filter media will have to operate approximately 891 hours per year. Therefore, the filter media will have to be replaced every 5 months, which results in an annual cost of \$78,000.

$$\frac{2,676,000 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{50 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} \cdot \frac{1 \text{ replacement}}{400 \text{ hrs}} \cdot \frac{\$35,000}{\text{replacement}} = \$78,000/\text{yr}$$

The filter media canisters are combined and disposed of with the vessels' solid waste. Because of the relative infrequency and small volumes disposed, the Navy does not expect any significant increase in their overall solid waste disposal cost.

The filter media canisters absorb the oil content of the oily bilge water. Because media canisters absorb the oil content, the filter media system does not produce waste oil that must be offloaded from the vessel.

Table 3-30 summarizes the annual recurring costs for a filter media system used on a CVN 68 Class vessel.

**Table 3-30. Annual Recurring Costs for Filter Media (CVN 68 Class)**

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost (\$K)
Within 12 nm	Navy	78
Beyond 12 nm	Navy	0

### 3.8.2.3 Total Ownership Cost (TOC)

Table 3-31 summarizes the TOC over a 15-year lifecycle for a filter media system on a CVN 68 Class vessel.

**Table 3-31. TOC for Filter Media (CVN 68 Class)**

Cost (\$K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	208	208
Total Recurring	869	869
TOC (15-yr lifecycle)	1080	1080
Annualized	91.5	91.5

### 3.8.3 Applicability of the Filter Media Analysis to New Design Vessels

The practicability and operational impact of using filter media systems on new design vessels in this vessel group are expected to be similar to the impact on existing vessels in this group, as represented by CVN 68 Class vessels. The installation cost would be different for new design vessels, however all other costs are not expected to change. Therefore, except for the installation cost and the adjusted TOC, this new design analysis refers to Sections 3.8.1 and 3.8.2 for all other feasibility factors. As discussed in Section 1.2, to estimate the new design installation cost, a factor of 67 percent was applied to the filter media installation cost estimate for existing

vessels within this group. Using this factor, the assumed installation costs for the new design CVN 68 vessel group is \$78,300, per vessel. The projected total initial cost for a filter media system aboard these new design vessels is \$169,000, per vessel. Table 3-32 summarizes the costs for these new design vessels.

**Table 3-32. TOC for Filter Media on New Design Vessels (CVN 68 Class)**

<b>Cost (\$K)</b>	<b>Vessel Operation Within 12 nm</b>	<b>Vessel Operation Within + Beyond 12 nm</b>
Total Initial	169	169
Total Recurring	869	869
TOC (15-yr lifecycle)	1037	1037
Annualized	88.2	88.2

### 3.9 MEMBRANE FILTRATION

The following sections discuss the feasibility and cost impacts of installing and operating a membrane filtration [ultrafiltration (UF)] secondary treatment OWS unit on-board CVN 68 Class vessels. The polishing unit consists of UF membranes and is designed to treat OWS effluent before being discharged overboard.

#### 3.9.1 Practicability and Operational Impact Analysis – Existing Vessels

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of membrane filtration.

##### 3.9.1.1 Space and Weight

A 50-gpm UF unit was selected as the secondary MPCD. Although primary OWSs installed on-board CVN 68 Class vessels generally have a combined processing rate of approximately 100 gpm, due to space constraints, the Navy is planning to install the 50-gpm UF unit on-board CVN 68 Class vessels. The Navy expects one unit to be sufficient for processing the amount of bilgewater generated within 12 nm where an effluent with lower oil concentration is most critical. Once beyond 12 nm, the vessel will operate its primary OWS and continue to operate in compliance with regulatory requirements. Table 3-33 summarizes the space and weight of a 50-gpm UF unit.

**Table 3-33. Membrane Filtration Unit Specifications (CVN 68 Class)**

<b>Physical Properties</b>	<b>Number of Units</b>	<b>Capacity</b>	<b>Size (ft.) L x W x H</b>	<b>Maintenance Envelope (ft.)</b>	<b>Volume (ft<sup>3</sup>)</b>	<b>Weight (lbs.) Dry/Flooded</b>
Per unit	1	50 gpm	24.5 x 3 x 6	26.5 x 5 x 8	440	9,200/12,000
Total (To achieve required processing capacity)	1	50 gpm	24.5 x 3 x 6	26.5 x 5 x 8	440	9,200/12,000

Due to space constraints in the OWS room, the UF unit will need to be installed in a different space such as the main machinery room. According to a ship check conducted by the Navy's AIT, some structural modifications and minor relocation of existing piping, cabling, or equipment is required to allow space for the equipment. Ventilation, lighting, and alarm systems will also need to be installed as well as new bulkheads.

UF membrane units are designed for single-deck operation. They can be provided to the installing activity fully assembled, or designed for easy disassembly into components small enough to fit through standard watertight doors.

Installing a 50-gpm membrane system on CVN 68 Class vessels would have space and weight impacts. Installation of 50-gpm membrane systems will also have significant impacts on machinery room space. However, based on preliminary 50-gpm membrane designs, these impacts will not be prohibitive.

#### ***3.9.1.2 Personnel/Equipment Safety***

There are no unusual personnel or equipment safety hazards associated with membrane systems. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While membrane systems require electrical power and operate under high pressures, observing standard shipboard safety procedures for handling electrical equipment and pressurized systems should be adequate. A Failure Mode, Effects and Criticality Analysis (FMECA) was generated for the UF system used on the USS CARNEY (DDG 51 Class vessel). The FMECA lists potential system failures according to their relative probability of occurrence, identifies safety hazards resulting from those failures, and recommends safety practices to reduce the associated safety risk. Applicable safety practices recommended by the FMECA will likely be implemented in conjunction with UF system installation on-board the CVN 68 Class vessels.

#### ***3.9.1.3 Mission Capabilities***

The installation and operation of a UF membrane on CVN 68 Class vessels is not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

#### ***3.9.1.4 Personnel Impact***

UF systems run in automatic mode, but require some basic oversight while the unit is operating. It is assumed that because a secondary OWS unit runs in conjunction with a primary OWS unit, the secondary units will not require significant additional oversight. Therefore, operator oversight hours associated with secondary units are assumed to be zero.

The waste oil removed from the bilgewater by the UF system must be transferred to a shore facility. This transfer requires three workers per event as described under Section 3.1.1.4. The labor hours associated with oversight of transfer of waste oil produced by a UF system on CVN

68 Class vessels are calculated by dividing the waste oil volume to be offloaded (1 percent of the total primary MPCD effluent) by the waste oil pump rate (90 gpm) and multiplying by the number (three) of crew members.

$$\frac{26,760 \text{ gal}}{\text{yr}} \cdot \frac{\text{min}}{90 \text{ gal}} \cdot \frac{\text{hr}}{60 \text{ min}} \cdot \frac{3 \text{ hrs labor}}{\text{hr}} = 15 \text{ hrs labor/yr}$$

Maintenance tasks and frequency for a 50-gpm membrane system (prototype) are assumed to be the same as those for the 10-gpm membrane units being used on DDG 51 Class vessels. However, because a 50-gpm system includes approximately 5 times as many membranes that require cleaning, the hours for certain tasks are assumed to be proportionately higher.

Annually, the membrane filtration system requires approximately 14.9 personnel hours of time-based maintenance, 12.5 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 3-34 and Table 3-35 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for a membrane filtration system. Table 3-36 provides the annual labor hours required to operate and maintain the proposed MPCD discussed in this section.

**Table 3-34. Membrane Filtration System Time-Based Maintenance Hours (CVN 68 Class)**

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Clean and inspect permeate flow sensor	0.2	3 months	0.8
Clean and inspect recirculation loop temperature sensor	0.2	3 months	0.8
Clean and inspect continuous level transducer	0.2	6 months	0.4
Clean and inspect high level sensor probe	0.2	6 months	0.4
Calibrate pressure gauges	5.0	12 months	5
Clean and inspect recirculation pump suction valve	1.8	12 months	1.8
Clean membranes (no MRC; for scheduling only. Perform CLEAN cycle. Perform quarterly and when membrane resistance is greater than 100% as indicated on the control panel)	0.5	3 months	2
Clean and inspect membrane system control panel	1.6	6 months	3.2
Inspect membrane system grounding straps	0.1	12 months	0.1
Perform lamp test of membrane system control panel; measure insulation resistance.	0.1	3 months	0.4
Total Annual Labor per unit			14.9
Total Annual Labor per vessel			14.9

**Table 3-35. Membrane Filtration Condition-Based Maintenance Hours (CVN 68 Class)**

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 892 operation hours within 12 nm)	Annualized Maintenance Hours (based on 0 operation hours beyond 12 nm)
Replace membranes (performed shoreside)	3	2400	1.11	0
Drain membrane system	1	100	8.9	0
Fill membrane system with water	1.0	500	1.8	0
Replace feed pump mechanical seal. Inspect internal parts	2.5	10000	0.22	0
Replace recirculation pump mechanical seal. Inspect internal parts	5	10000	0.45	0
Total Annualized Hours			12.5	0

**Table 3-36. Membrane Filtration Annual Labor Hours (CVN 68 Class)**

	MPCD Option: Membrane Filtration
Operator Hours Within 12 nm	15
Operator Hours Beyond 12 nm	0
Condition-based Maintenance Within 12 nm	12.5
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	14.9
Total Time	42

### 3.9.1.5 Consumables, Repair Parts, and Tools

On vessels equipped with the UF system, membranes are scheduled for replacement after approximately 2400 hours of use. During replacement, a new, clean set of membranes is installed in the UF system and the old, used ones are sent to shore to be cleaned. This regular maintenance does not require any consumables, because the membranes are exchanged. Furthermore, UF systems do not require any unusual repair parts or tools.

### 3.9.1.6 Interface Requirements

Table 3-37 summarizes the UF system interface requirements below. These requirements are not expected to have a substantial impact on CVN 68 Class vessels.



**Table 3-37. UF Unit Interface Requirements (CVN 68 Class)**

<b>Shipboard System</b>	<b>Interface Requirement (50-gpm system)</b>
Electric Power	35 kW (47 hp), 440 Volts/3 Phase/ 60Hz
Compressed Air	80 to 100 psi, 5 scfm (operate valve actuators)
Potable Water	Flush Sub-System: 10 gpm, 30 psi
Drainage	Concentrate from recirculation sub-system drains to WOT. When back flushing membranes, oily waste flushed from system is diverted to OWHT.

### **3.9.1.7 Control System Requirements**

The UF system operates automatically in response to the primary OWS. In addition, a UF unit installed on a CVN 68 Class vessel may be equipped with an OCM to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than the predetermined desired concentration, the OCM will redirect the effluent back to the OWHT to be processed again by the OWS and UF. The UF system does not have any unique control system requirements.

### **3.9.1.8 Other/Unique Characteristics**

No other/unique characteristics have been identified with respect to this MPCD option.

## **3.9.2 Cost Analysis – Existing Vessels**

The following cost data and calculations are provided to allow the reader to compare relative costs associated with using and installing the UF membrane MPCD on a CVN 68 Class vessel.

### **3.9.2.1 Initial Cost**

The UF system (i.e., one unit) procurement cost is \$600,000 (Smith, 1999). Based on ship drawing analysis and a CVN 73 (CVN 68 Class vessel) ship check, the Navy estimates that installation of a UF membrane on a CVN 68 Class vessel would cost \$354,600 per vessel (Navy, 2000). To install the unit, some structural modifications and minor relocations would be required to allow enough space in the main machinery space. In addition, piping is required between the UF unit in the main machinery space and the primary OWS in the OWS room. The installation would require approximately 12 weeks to complete. Technical manuals cost approximately \$85,000 (\$9,440 per vessel) to develop a 150 page manual (Gallagher, 1999). The development of technical drawings will cost \$38,640 (\$4,293 per vessel). The cost for training materials is approximately \$9,330 (\$1,037 per vessel) (Smith, 2001). The total initial cost of a UF membrane system on a CVN 68 Class vessel is \$968,000 per vessel.

### **3.9.2.2 Recurring Cost**

This MPCD requires 42 personnel hours per year for operation, condition-based maintenance and time-based maintenance within 12 nm, as explained under Section 3.9.1.4. The number of annual labor hours multiplied by the \$22.64 hourly MPCD operator labor rate produces the annual labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{42 \text{ hrs labor}}{\text{yr}} = \$960/\text{yr (within 12 nm)}$$

The labor required to transfer waste oil generated by the gravity coalescence system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose of the waste oil at no charge for Navy vessels.

Table 3-38 provides annual recurring costs for a UF membrane system on-board a CVN 68 Class vessel.

**Table 3-38. Annual Recurring Costs for UF Membrane System (CVN 68 Class)**

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost (\$K)
Within 12 nm	Navy	.96
Beyond 12 nm	Navy	0

### 3.9.2.3 Total Ownership Cost (TOC)

Table 3-39 summarizes the TOC and annualized cost over a 15-year lifecycle for a UF membrane system on a CVN 68 Class vessel.

**Table 3-39. TOC for UF Membrane System (CVN 68 Class)**

Cost (\$K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	968	968
Total Recurring	11	11
TOC (15-yr lifecycle)	979	979
Annualized	83.2	83.2

### 3.9.3 Cost Analysis – New Design Vessels

The practicability and operational impact of using UF membrane systems on new design vessels in this vessel group are expected to be similar to the impact on existing vessels in this group, as represented by CVN 68 Class vessels. The installation cost would be different for new design vessels, however all other costs are not expected to change. Therefore, except for the installation cost and the adjusted TOC, this new design analysis refers to Sections 3.9.1 and 3.9.2 for all other feasibility factors. As discussed in Section 1.2, to estimate the new design installation cost, a factor of 67 percent was applied to the UF membrane system cost estimate for existing vessels within this group. Using this factor, the assumed installation costs for the new design CVN 68 vessel group is \$237,000, per vessel. The projected total initial cost for a UF membrane system aboard these new design vessels is \$852,000, per vessel. Table 3-40 summarizes the costs for these new design vessels.

**Table 3-40. TOC for UF Membrane System on New Design Vessels (CVN 68 Class)**

<b>Cost (\$K)</b>	<b>Vessel Operation Within 12 nm</b>	<b>Vessel Operation Within + Beyond 12 nm</b>
Total Initial	852	852
Total Recurring	11	11
TOC (15-yr lifecycle)	863	863
Annualized	73.3	73.3